NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL MEMORANDUM

No. 1088

A PHOTOGRAPHIC PROFILE RECORDER FOR AIRSCREWS AND WING MODELS

By R. Kuhl and K. Raab

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A PHOTOGRAPHIC PROFILE RECORDER FOR AIRSCREWS AND WING MODELS[1]

By R. Kuhl and K. Raab

This report describes an apparatus enabling measurements of bodies to be made photographically, where other methods would be difficult. It is especially useful in the case of airscrews and wing models. The utility of the machine is shown by a few examples of profile records.

BASIC FEATURES

As the generality of measuring instruments are not well adapted to checking the measurements of parts such as airscrews and wing models, a small photographic apparatus was developed several years ago according to a suggestion by Professor Betz, at the Aerodynamic Experimental Laboratories at Göttingen suitable for airscrew models[2]. The favorable results achieved and inquiries received from constructors, led to a larger machine being made, suitable for measuring full size airscrews and wing models. The increase in size of the machine due to the full size airscrews which were now to be measured, called for substantial modifications in the design, which is capable of dealing with models of 35-millimeter depth of profile, while the length may be 3 meters or more.

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[1] "Ein photographisches Profil-Aufnahmegerät für Luftschrauben und Modelltragflügel." Luftwissen, vol. 5, no. 5, 1938, pp. 183-185.

[2] The first model of this apparatus was described in the Wissenschaftliche Gesellschaft für Luftfahrt Yearbook 1939, an improved model in the fourth issue of "Ergebnisse der Aerodynamischen Versuchsanstalt Göttingen."

NOTE: Reprint of R.T.P. 3 Translation No. 2197; issued by the Ministry of Aircraft Production, London, England.

Naturally, the profiles of other experimental parts can be recorded photographically; for example, fuselage models, float models, struts or the like, such as full size airscrews, girder sections, bar or rod sections, and so forth.

In order to have a machine easy to handle and using standard photographic plates of 13 × 18 centimeters, the photos were arranged for a scale reduction of 1 to 2. In this way the manufacture of the apparatus, running costs, and also the space required, are considerably reduced.

The measurements include the profiles and their relative positions. The coordinates of the profiles can be determinedd numerically with the help of a diagram of coordinates arranged on a definite scale (e. g. with the special apparatus made by Carl Zeiss, and described in the 3rd issue of "Ergebnisse der Aerodynamischen Versuchsanstalt Göttingen"); or they can be compared with the drawings of the models.

As will be seen from the diagram (fig. 2) a profile of the unlighted object is illuminated by a luminous plane and photographed. At the same time, the camera, indicated in the diagram by the sensitized plate and objective, is caused to revolve round the profile which is being photographed, and the sensitized plate is traveled in relation to the objective, by means of a cinematograph movement, so that it does not revolve on its own axis, but only moves along its circular path, with its plane parallel to the objective.

In order to secure a satisfactory picture of the profile certain geometrical conditions must be fulfilled. While the camera in following its orbit is obliged to turn, the plate must be turned back with respect to the camera through an angle equal to that turned through by the camera and its holder on their axis. Further, the planes of the photographic plate and luminous plane must be exactly parallel to each other and must be at right angles to the axis of rotation of the camera holder and to that of the plate. The last condition to be fulfilled is the optical one. The optical center of the objective must lie on the line joining the intersection between the plane of the plate and the axis of rotation of the plate with the intersection of the luminous plane and the axis of rotation of the camera.

While the first two requirements can be fulfilled by accuracy of manufacture and erection, the last mentioned condition can be met by the arrangement provided for adjusting the objective.

DESCRIPTION OF THE APPARATUS

Details of design and method of operating the machine are given below.

Figure 3 is a side elevation of the apparatus, which consists of three principal parts:

1. Bedplate [1] with the two bearing pedestals [2,3] and outrigger bracket [4]

2. Camera holder [5] with camera [6] and the lighting arrangement [20,21]

3. Wing support or propeller clamp [8]

A fixed helical spur wheel [9] is bolted to the bearing pedestal [2], the axis of this wheel coincides with the axis of rotation of the camera holder. A pinion [10] gears in with the aforesaid spur wheel, is supported by its bearing, carried in the camera body (fig. 4) and as the camera holder [5] revolves the pinion is carried round on the stationary helical spur wheel [9]. Inside the camera plate holder housing is mounted a spurwheel [11] on the same spindle as the helical pinion [10];([11] is shown dotted in fig. 4). The spurwheel [11] is geared to the spurwheel [12] which also has its bearing in the camera plate holder housing and supports the plate holder carrier [13]. The gear ratios of the wheels which are geared together are identical, so that the relative angular movement of the camera holder and hence also of the camera with respect to the plate holder and plate are the same. Careful manufacture and a minimum of backlash in the gears are necessary as otherwise complete profiles are unobtainable.

The camera holder is a hollow cylindrical body, open at both ends; thus it is possible to accomodate very long models. It is rotatably mounted on four pairs of ball bearings [15] and is perforated to give passage to light reaching the objective. In addition, brakes [17] are mounted on the bearing pedestal [3], by means of which the camera holder can be gripped in any desired position. Adjustable enclosed counterweights [18] are placed in positions to counterbalance the weights of the camera [6] and the lighting arrangements (fig.5) [20, 21], respectively.

The objective [19] is secured to the camera (fig. 4). It provides the necessary vertical and transverse adjustments

with dovetail guides and worm-and- wheel gear for axial adjustment. The objective used was a "wide-angle aristostigma" supplied by Hugo Meyer, Görlitz — the lens aperture is 1:9 and focal length 16 centimeters. This objective was chosen on account of its far-reaching lack of distortion, a feature which was of special importance as owing to the scale reduction to half size, the accuracy of the record made had to be twice as great as when the profile is reproduced to full size. This requirement was more difficult to meet owing to the wide angle of the image, of up to 80°, resulting from the oblique position of the objective in respect to the image on the plate. Generally speaking, the different cross sections of the body to be measured will simply be photographed, one over the other. In case the individual profiles coincide too closely so as to lead to confusion, the plate must be suitably displaced between the exposures. For this purpose the plate holder carrier with the plate holder is mounted on slides.

The lighting unit (fig. 5) consists of the lamp housing [20] with five low-voltage Osram lamps placed in line, which produce a luminous plane with the help of the slot plates [21] which provide a slot of adjustable width. The whole arrangement is supported by a three-point bearing on the camera holder [5], in order to be able to set the luminous plane exactly parallel to the plane of the sensitized plate. The current is conducted via two slip rings [22] (fig. 3) mounted on the camera holder.

The support or clamp [8] for holding models [16] is of steel tubular construction with suspension wires for holding the models, designed so as to allow the least possible obstruction of light between the object and the objective. The steel tubular cage is supported by four rollers. In this way the cage can be moved along the rails [14]. One of the rails is graduated in millimeters and by means of verniers marked on the cage the required movements can be measured off exactly.

Four reference markers painted white 23 (fig. 3) serve to fix the points of a rectangular system of coordinates on the photographic plate. The markers situated vertically above each other determine a vertical line and those lying in a horizontal position indicate a horizontal plane parallel to the plane of horizontal displacement of the cage. These markers appear as short lines on the photographs, and provide points of reference on every photograph for the system of

coordinates[1] – for example, in the case of reconstruction of a wing with trapezoid taper from the wing halves appearing on each of two plates.

EXAMPLES OF APPLICATIONS

In figures 6 to 8 profile photos are shown of two wing models and of one airscrew, taken with the apparatus here described. White powder was spread on the models before taking the photographs in order to shorten the time for illuminating them. Figure 6 shows on the same plate profiles of the wing mounted in the cage as seen in figures 1 and 3. The profiles shown in full lines are photos taken of the starboard half of the wing; whereas the dotted lines refer to the port side. The dotted lines were obtained by removing the powder at suitable intervals. By setting up the profiles of the two wing halves in opposition, the accuracy of construction of the models can be easily recognized.

Figure 7 shows a profile with flap deflected and wide slot. Figure 8 shows an airscrew profile – full size. In taking profiles of airscrews, two of the markers which mark the axes of the coordinates, must be located accurately in the axis of the screw and must be included in the photograph. The perpendicular to this axis will accordingly represent the plane of rotation of the airscrew. The angle between this plane and a chord of the profile will give the pitch angle.

Translation by H. I. Lewenz.

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[1]For printer's reasons the marks for the coordinates in figures 6 to 8 have been omitted.

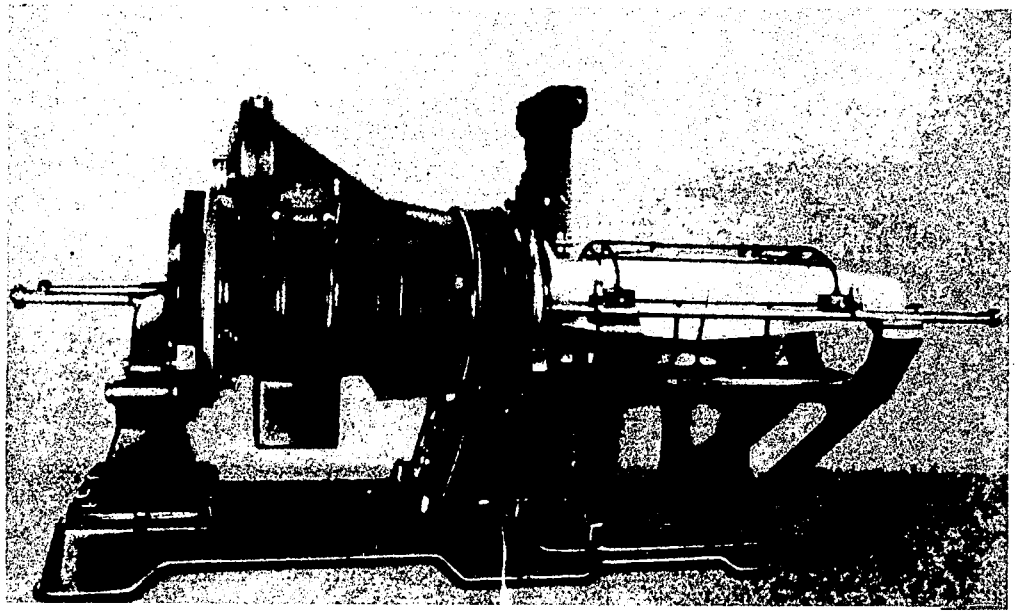
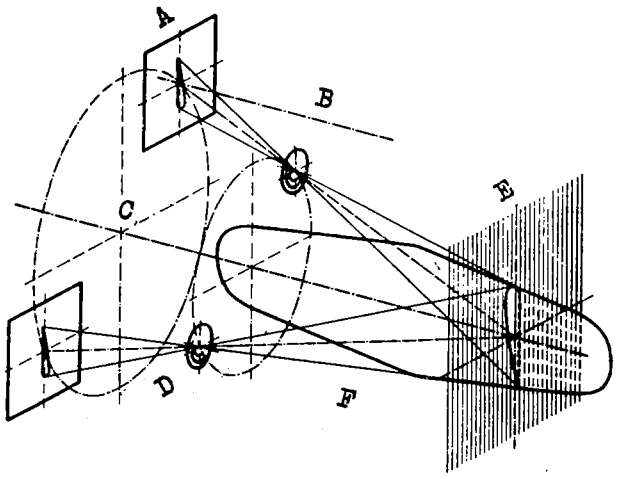
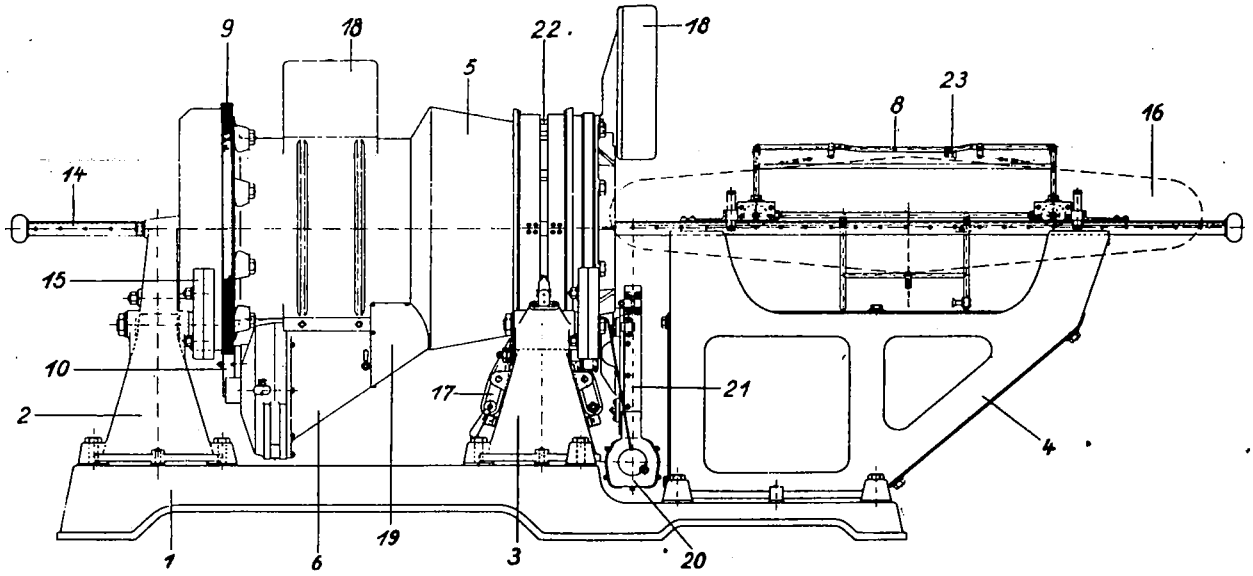


Figure 1.- General view of the profile recorder.



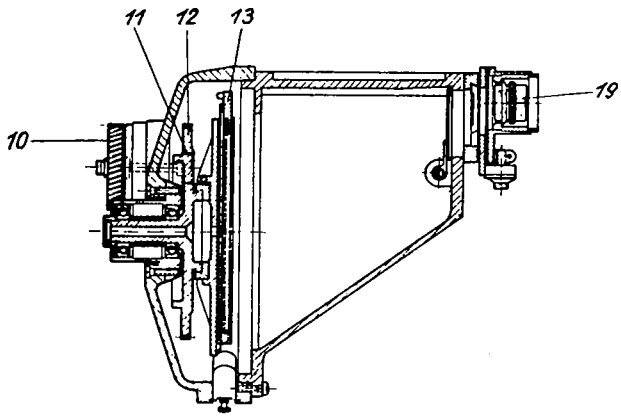
A, sensitized plate.
B, axis of rotation of the plate.
C, axis of rotation of the camera.
D, objective.
E, luminous plane.
F, model of wing with trapezoidal taper.

Figure 2.- Diagrammatic illustration of the photographic process.



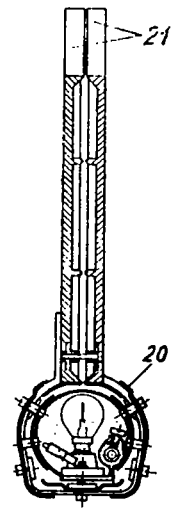
1, bedplate.
2, bearing pedestals.
3, bearing pedestals.
4, outrigger bracket.
5, camera holder.
6, camera.
8, support for wing model or propeller.
9, fixed spurwheel.
10, pinion.
14, rails.
15, pairs of ball bearings (4 in all).
16, model.
17, brake lever.
18, balance weights (enclosed).
19, objective (enclosed).
20, lighting arrangement.
21, lighting arrangement.
22, slip rings.
23, reference markers.

Figure 3.- Side elevation of profile recorder for wing models.



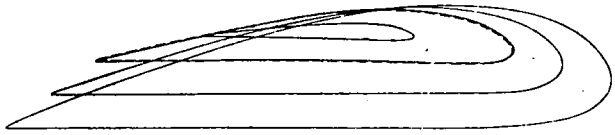
10, pinion.
11, spur wheel (shown dotted).
12, spur wheel drive for plate holder.
13, plate holder carrier.
19, objective.

Figure 4.- Camera with plate holder housing.



20, lamp housing.
21, slot plates.

Figure 5.- Lighting arrangement.



——— starboard profile: y = 50, 250, 450, 590 mm from centre of wing.
– – – port profile: y = 450 mm from centre of wing.

Figure 6.- Profile of a trapezoidal wing.

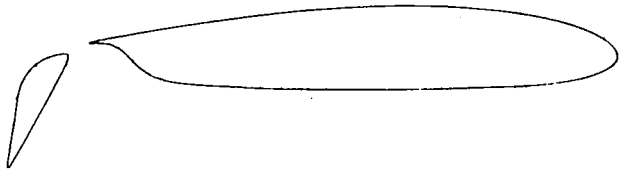


Figure 7.- Simple slotted flap profile.

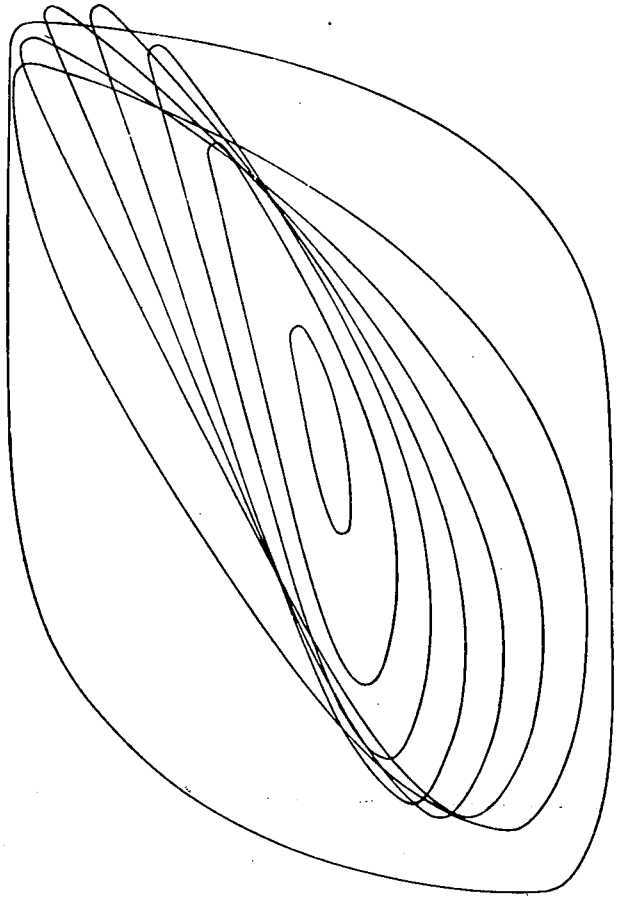


Figure 8.- Full size profile of an airscrew. D = 2500 mm; H = 1600 mm. Profiles taken at distances of 150, 300, 450, 600, 750, 900, 1050, 1230 mm from the axis of the propeller.